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Laramide stratigraphy of the Little Hatchet Mountains, southwestern New Mexico

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Abstract

Cretaceous–Paleogene rocks of the Little Hatchet Mountains in southwestern New Mexico include the Ringbone, Hidalgo, and Skunk Ranch Formations. The Ringbone Formation is up to 1,600 m (5,250 ft) thick and ranges in age from late Campanian through early Maastrichtian. It was deposited in alluvial-fan, fluvial, and lacustrine environments. The Hidalgo Formation, which overlies the Ringbone, comprises 1,700 m (5,500 ft) of volcanic breccia, flows, and tuff. Radiometric age control on rocks collected in the Little Hatchet Mountains indicates an age range of 71.4 to 61.7 Ma for the Hidalgo Formation. The Skunk Ranch Formation is up to 490 m (1,605 ft) thick and Paleocene–Eocene in age, based on ostracodes and gastropods. It overlies volcanic flows in the uppermost part of Ringbone and contains an andesite breccia in its middle member, defined here. These volcanic rocks are interpreted as flows associated with the Hidalgo Formation; thus, the Skunk Ranch is inferred to be correlative, at least in part, with the Hidalgo Formation. The Skunk Ranch Formation accumulated in alluvial-fan and lacustrine settings.

Cretaceous–Paleogene strata of the Little Hatchet Mountains record the intimate association of volcanism with Laramide deformation in southwestern New Mexico. In addition, the stratigraphy lends support to proposed models of two periods of crustal deformation during the Laramide orogeny of the southwestern United States. These two periods include latest Cretaceous basement-block uplift associated with development of intermontane (Ringbone) basins and a Paleocene–Eocene (Skunk Ranch) phase of shortening that deformed the earlier basins and modified patterns of sedimentation. Late-phase deformation was accompanied by formation of both reverse and normal faults.

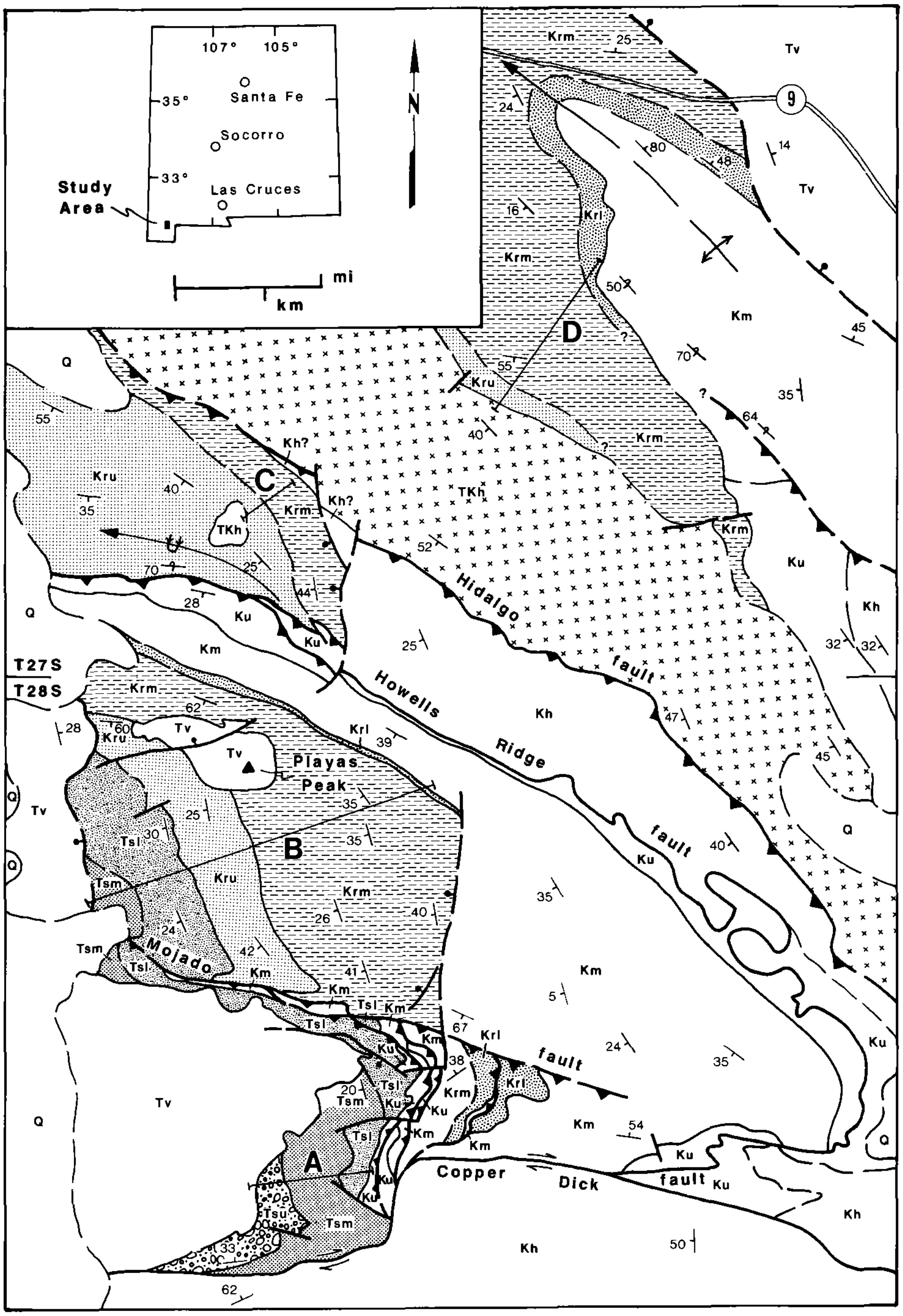

FIGURE 1—Geologic map of northern part of Little Hatchet Mountains, modified from Zeller (1970), Rosaz (1989), and Hodgson (1991). Generalized traces of measured sections in Fig. 3 indicated by line segments A, B, C, and D. **Kh**, Hell-to-Finish Formation; **Ku**, U-Bar Formation; **Km**, Mojado Formation; Ringbone Formation, divided into lower (**Krl**), middle (**Krm**), and upper (**Kru**) members; **TKh**, Hidalgo Formation; Skunk Ranch Formation, divided into lower (**Tsl**), middle (**Tsm**), and upper (**Tsu**) members; **Tv**, Eocene and Oligocene volcanic rocks; **Q**, Quaternary deposits. Contacts between members of Ringbone located very approximately in northeast corner of map. Tertiary intrusive rocks in the Hidalgo Formation northeast of the Hidalgo fault are not shown. Western and eastern map boundaries are edges of R16W.

Introduction

The sedimentologic record of the Laramide orogeny in the southwestern United States consists of widely scattered exposures, diverse lithologies, and scant diagnostic fossil material. These characteristics impede correlation of mappable units and obscure the tectonic origin of some units. Uppermost Cretaceous strata inferred to represent Laramide deposits are widely distributed in southeastern Arizona and northern Sonora (Dickinson et al., 1989); Paleogene deposits of probable Laramide origin are likewise present in southwestern and south-central New Mexico (Seager and Mack, 1986). ☞

Lasky (1947)	Zeller (1970)	This Report	Age
Skunk Ranch Conglomerate	Ringbone Formation	Skunk Ranch Formation	Paleocene-Eocene
Hidalgo Volcanics	Hidalgo Volcanics	Hidalgo Formation	?
Playas Peak Formation	Ringbone Formation	Ringbone Formation	Late Cretaceous
Howells Ridge Formation			
Ringbone Shale			
Broken Jug Limestone			

FIGURE 2—Comparison of stratigraphic terminology of this report with previous stratigraphic nomenclature of the Little Hatchet Mountains. Age interpretation applies to this report only: Lasky (1947) considered the illustrated formations to be Early Cretaceous age based on fossils in the Howells Ridge Formation, part of which is now considered U-Bar Formation (Zeller, 1970), and in the Corbett Sandstone, not shown but placed by Lasky between Howells Ridge and Playas Peak Formations and now considered Mojado Formation (Zeller, 1970). Neither of the previous stratigraphic successions is depicted in its original sequence because each contains correlation errors.

With the exception of the Cabullona Basin in northern Sonora (Lucas and González-León, 1990), the most complete, known Laramide succession occurs in the Little Hatchet Mountains of southwestern New Mexico (Zeller, 1970). Although the range is structurally complex, the Upper Cretaceous and Paleogene stratigraphy is reasonably complete and well exposed. The Little Hatchet Mountains contain an excellent record of the Laramide history of the southwestern United States. Laramide rocks are exposed in four blocks separated by faults (Fig. 1), but correlation of stratigraphic sections permits a reconstruction of the original stratigraphic relationships.

In this paper, we summarize our recent work on the Laramide stratigraphy of the Little Hatchet Mountains. The data include measured and correlated stratigraphic sections (Basabilvazo, 1991; Wilson, 1991), geologic mapping (Hodgson, 1991), biostratigraphic control (Lawton et al., 1990; Lucas et al., 1990), and a new $^{40}Ar/^{39}Ar$ date. The new age and recognition of key correlative intervals require revision of the stratigraphic sequence in the range. In addition, the depositional record supports the hypothesis that Laramide deformation occurred in two stages: 1) a late Campanian–early Maastrichtian episode of transpressional block uplift and basin formation (Seager, 1983); 2) a Paleocene–early Eocene episode of thrusting or convergent wrenching (Hodgson, 1991). The volcanism appears to have begun during the first episode of deformation and continued into the second.

Previous stratigraphic nomenclature

Although only a small body of previously published work exists from the Little Hatchet Mountains, the stratigraphic nomenclature is diverse (Fig. 2), partly as a result of the complex structural geology of the range. Strata considered by us as Ringbone Formation were originally assigned by Lasky (1947) to the Broken Jug Limestone, the Ringbone Shale, the Howells Ridge Formation, the Playas Peak Formation, and the Skunk Ranch Conglomerate (lower part), in ascending order. The Corbett Sandstone, considered by Lasky to lie between the Howells Ridge and Playas Peak Formations, is actually a Lower Cretaceous formation and is not included in our Ringbone Formation. Lasky assigned a thick sequence of andesitic breccia, tuff, and flows to the Hidalgo Volcanics. He applied the name Skunk Ranch Conglomerate to the youngest sedimentary bedrock unit in the range. The Skunk Ranch Formation of this report is synonymous with Lasky's Skunk Ranch, except near Playas Peak (Fig. 1), where our upper member of the Ringbone corresponds to the lower part of his Skunk Ranch Conglomerate. Zeller (1970) included all of the above formations named by Lasky (1947), except the Corbett Sandstone, in the Ringbone Formation, although he retained the name Hidalgo Volcanics.

Neither of the previous stratigraphic studies correctly depicts the proper age or sequence of lithologic units in the Little Hatchet Mountains. Lasky believed all the stratigraphic units to be Early Cretaceous age on the basis of marine fossils in the Howells Ridge Formation and Corbett Sandstone. These strata have been reassigned, in part, to the Lower Cretaceous U-Bar and Mojado Formations, respectively, by Zeller (1970). Zeller considered the Ringbone to be Late Cretaceous or early Tertiary age on the basis of the fossil palm, Sabal, now referred to *Sabalites* (Zeller, 1970; Lucas et al., 1990). The overlying Hidalgo Volcanics were regarded by Zeller as early Tertiary based on the presence of fossil dicotyledonous wood.

Radiometric dating of the Hidalgo Formation in the northern part of the Little Hatchets and inferred equivalents in the Pyramid Mountains to the northwest supports a Cretaceous–Tertiary age for the volcanic pile. An andesite flow in the upper part of the Ringbone Formation, sampled by Lasky and studied later by Marvin et al. (1978), yielded a zircon fission-track age of 69.6±3.2 Ma. Porphyritic basalt from the Hidalgo Formation in an area east of that studied by us yielded whole-rock K-Ar ages of 63.0±2.0 Ma and 61.7±2.2 Ma (Loring and Loring, 1980). In the Pyramid Mountains, about 35 km (21 mi) northwest of the Little Hatchet Mountains, volcanic rocks assigned to the Hidalgo Formation have yielded zircon fission-track ages of 67.3±7.1 Ma, 57.9±2.7 Ma, and 54.9±2.7 Ma (Marvin et al., 1978). The younger ages may be reset and probably record thermal effects from intrusion of the Lordsburg stock (Loring and Loring, 1980).

Stratigraphy and age of Laramide strata

Uppermost Cretaceous and Paleogene rocks of this report are included in the Ringbone, Hidalgo, and Skunk Ranch Formations, in ascending order (Fig. 2). These units do not occur together in a single stratigraphic sequence anywhere in the range, in part because the Hidalgo and Skunk Ranch are lateral equivalents and in part because shifting loci of deposition locally resulted in erosion of the Ringbone prior to Skunk Ranch deposition. Uncertainty remains about the mutual relationships of the Hidalgo and Skunk Ranch Formations; however, we believe the correlations presented here are correct in general. The Laramide units are described briefly in the following sections and new data pertaining to their ages summarized.

Ringbone Formation

The Ringbone Formation consists of conglomerate, sandstone, siltstone, and mudstone with a maximum measured thickness of 1,600 m (5,250 ft; Basabilvazo,

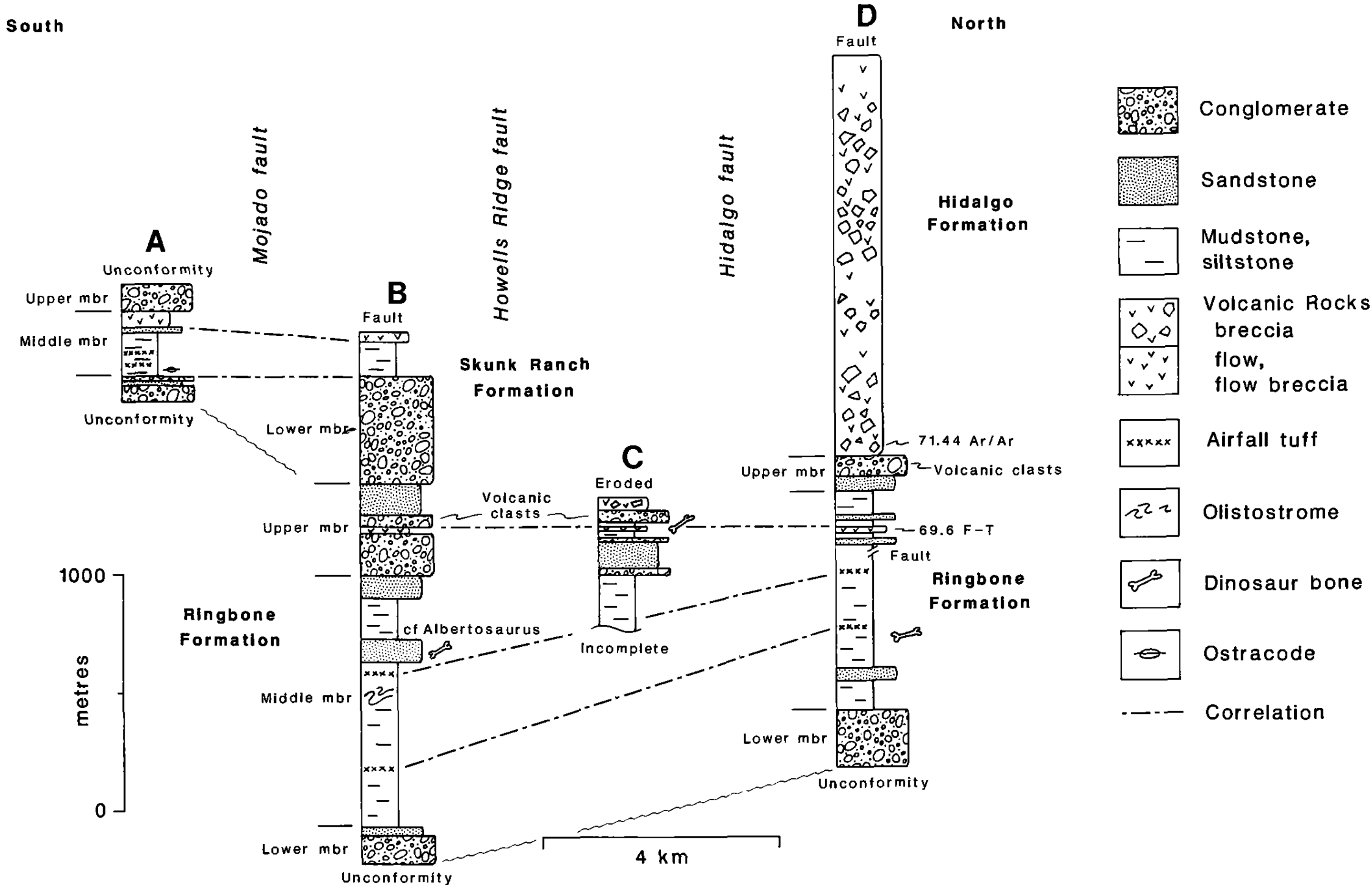

FIGURE 3—Stratigraphic relationships of Upper Cretaceous and Paleogene rocks, northern part of Little Hatchet Mountains, New Mexico. Locations of sections are in Fig. 1. Lithologies shown are generalized and represent dominant rock type of a given interval. Faults indicated are reverse faults that separate each measured section (Fig. 1; Hodgson, 1991). Fission-track age indicated beside column D was reported by Marvin et al. (1978) for an andesite flow in the upper member of the Ringbone Formation sampled by Lasky (1947).

1991). Three informal members are mappable in the northern part of the Little Hatchet Mountains (Basabilvazo, 1991; Hodgson, 1991). Descriptions below are taken largely from Basabilvazo (1991).

The lower member is about 100 m (330 ft) thick and rests unconformably on the Lower Cretaceous Mojado Formation in the study area (Zeller, 1970; Hodgson, 1991). It consists of sedimentary-clast conglomerate and sublithic sandstone in beds 1–15 m (3–50 ft) thick. Pebbles and cobbles were derived from Paleozoic and Lower Cretaceous sedimentary formations. Large clasts, which reach a maximum dimension of 1 m (3 ft), are composed exclusively of Lower Cretaceous limestone and limestone-clast conglomerate. This observation suggests that most of the Paleozoic limestone clasts are recycled from Lower Cretaceous conglomerate. Associated sandstone beds include both sedimentary sublitharenites and lithic arkoses (Basabilvazo, 1991).

The middle member is dominated by dark-gray mudstone with subordinate interbedded sandstone. Dramatic thickening occurs southward in the middle member near Playas Peak (Fig. 1; Basabilvazo, 1991). Silicic air-fall tuff beds up to 2 m (6 ft) thick are present in the mudstone. A single interval in the mudstone contains deformed sandstone beds and boulders of conglomerate and fossiliferous calcareous siltstone. This interval of soft-sediment deformation and slumping is about 10 m (33 ft) thick. Sandstone interbeds are lithic arkoses containing common volcanic-lithic fragments (Basabilvazo, 1991). The middle member records conditions characteristic of lacustrine and lacustrine-deltaic settings. The interval of soft-sediment deformation probably represents an olistostrome in a lake of considerable depth (Basabilvazo, 1991). Airfall tuff beds in the member are important markers that may be correlated between the southern and northern exposures of the unit (Fig. 3; Basabilvazo, 1991).

Dinosaur fossils and pollen constrain the age of the middle member of the Ringbone Formation. Fossil dinosaur remains, including bones and teeth, are widely distributed, both geographically and stratigraphically, in the middle member. Vertebrae and a tooth assignable to cf. *Albertosaurus* from the middle part of the member (Fig. 3, section B) indicate a late Campanian–Maastrichtian age by comparison with faunas of the San Juan Basin in northwestern New Mexico (Lucas et al., 1990). A pollen assemblage collected from the Ringbone somewhat upsection of the dinosaur fossils includes the form *Aequitriradites spinulosus* (Rosaz, 1989), which occurs only in upper Campanian strata of central Utah (Fouch et al., 1983).

The upper member of the Ringbone consists of cobble and pebble conglomerate and sandstone. Basal beds of the member abruptly overlie the middle member in southern parts of the study area and comprise conglomerate containing boulder-sized clasts. As in the lower member, the conglomerate contains mainly clasts of sedimentary rock types. Conglomerate decreases in abundance and clast size to the north and is replaced by interbedded sandstone and shale. The middle part of the member near Playas Peak (Fig. 3, section B) contains thin andesite flows (Hodgson, 1991) that provide a means of correlating the unit in the study area. Andesite clasts that occur in uppermost conglomerate beds of the Ringbone (Basabilvazo, 1991) resemble lithologies in the Hidalgo Formation and are inferred to have been derived from early Hidalgo deposits, which are time equivalents of the Ringbone. ☞

Hidalgo Formation

The Hidalgo Formation consists of basaltic and andesitic flows, flow breccia and tuff of intermediate composition approximately 1,700 m (5,500 ft) thick (Zeller, 1970). This thickness is a minimum because the upper part of the unit is truncated by the Hidalgo fault (Zeller, 1970; Hodgson, 1991). Basal beds of the Hidalgo rest with sharp contact on the Ringbone in northern outcrops. As noted above, flows in the upper part of the Ringbone suggest complex interfingering of epiclastic and volcanigenic units, the latter perhaps representing precursors of the Hidalgo volcanic sequence. Our understanding of the Hidalgo is preliminary, but it appears to be broadly divisible into three units of subequal thickness. The lower unit is a complex of dominant tuff breccia and flow breccia with subordinate air-fall tuff. The middle unit is poorly exposed, apparently dominated by fine-grained air-fall or ash-flow tuff. The upper unit consists of flows, flow breccia, and tuff breccia similar to the lower unit. The Hidalgo Formation is interpreted to represent the margin of a stratovolcano complex. The tuff breccias represent lahar deposits, which dominate the section.

We have obtained a $^{40}Ar/^{39}Ar$ age of 71.44 ± 0.19 Ma on a hornblende andesite from the base of the Hidalgo section (Fig. 3, section D). This age accords well with the biostratigraphic data from the underlying Ringbone and indicates that the lowermost Hidalgo Formation is somewhat older than indicated by previous fission-track and K-Ar ages. The protracted volcanic history indicated by ages obtained from different dating techniques suggests that the K-Ar and fission-track ages may be reset and need to be re-evaluated.

Skunk Ranch Formation

The Skunk Ranch Formation overlies the Ringbone Formation in the vicinity of Playas Peak but overlies the Lower Cretaceous U-Bar Formation in its southernmost exposures (Fig. 1). Identification of the base of the formation has been made by walking along beds from south to north and provides justification for moving the base of the Skunk Ranch upsection relative to its original base as defined by Lasky (1947). The base of Lasky's Skunk Ranch corresponds to the base of the upper member of the Ringbone described here.

The Skunk Ranch is divided into three informal members. All three members are present in the southern measured section (Fig. 3, section A), but the upper member is missing in the vicinity of Playas Peak as a result of omission by normal faulting. Descriptions of the members are taken from Wilson (1991).

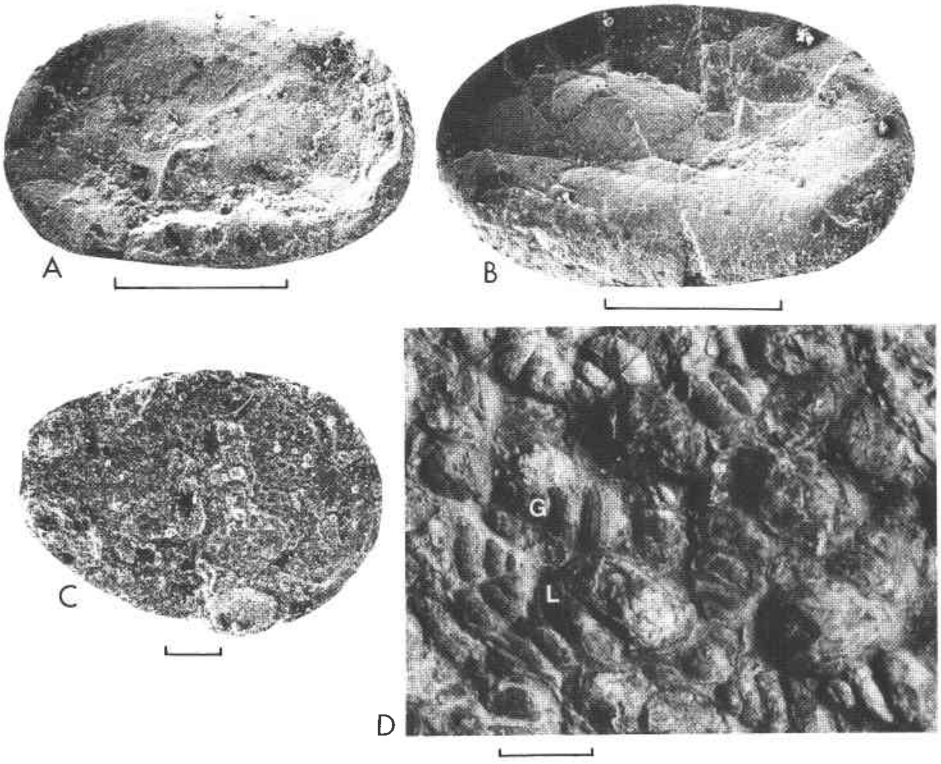

FIGURE 4—Ostracodes and gastropods from the Skunk Ranch Formation in the Little Hatchet Mountains. **A**, **B**, *Pseudoeocypris pagei*, left valves. **C**, *Bisulcocypridea arvadensis*, left valve. **D**, *Goniobasis* (**G**) and *Lioplacodes* (**L**) packstone. Bar scales are 500 μm for A and B, 100 μm for C, and 1 cm for D.

The lower member consists of boulder and cobble conglomerate interbedded with red sandy siltstone and olive-gray siltstone. Clast size in conglomerate decreases upsection. Basal boulder conglomerate beds contain clasts derived only from Lower Cretaceous units, the Hell-to-Finish, U-Bar, and Mojado Formations. Uppermost conglomerate beds contain oncolites and clasts coated with thin micrite rims. The member is approximately 110 m (360 ft) thick in the south; northward, across the Mojado fault (Hodgson, 1991), it thickens abruptly to nearly 450 m (1,475 ft). Both the lower and middle members are offset across the Mojado fault, with offset measuring tens of meters. In contrast, hundreds of meters of offset are required to juxtapose Ringbone and U-Bar beds across the same fault (Fig. 1; Hodgson, 1991). The lower member was deposited in alluvial-fan and braided-fluvial environments (Wilson, 1991). The upper part probably represents lake-margin deposits, possibly fan deltas.

The middle member is approximately 250 m (820 ft) thick. In its lower part, it consists of dominant dark-gray to olive-gray laminated mudstone with subordinate sandstone. In the middle part of the member, millimeter-scale siliceous laminae in the mudstone resemble varves. Sandstone beds are thin (5–30 cm; 2–12 inches) and commonly contain symmetrical ripples. Soft-sediment deformation is present in some sandstone intervals. Sandstone beds are arranged in successions to 2 m (6 ft) thick that thicken and coarsen upward. Each succession is abruptly overlain by mudstone. The upper part of the middle member consists of gray, monomict andesitic breccia capped by stromatolitic limestone about 10 m (30 ft) thick. The breccia is approximately 70 m (210 ft) thick in measured section A (Fig. 1) and thins southward and northwestward. It resembles flow breccia of the Hidalgo Formation, but we have not yet satisfactorily confirmed its Hidalgo source.

The middle member was deposited in a variety of lacustrine, lacustrine-delta, and lacustrine-margin environments (Wilson, 1991). An ostracode fauna (Fig. 4A–C) collected low in the unit includes the forms *Pseudoeocypris pagei* and *Cypridea arvadensis* (Lawton et al., 1990), now termed *Bisulcocypridea arvadensis* (Wilson, 1991). This assemblage indicates a Paleocene to Eocene age for the middle member of the Skunk Ranch Formation. Fossil beds in the same stratigraphic interval include the freshwater gastropods, *Goniobasis* and *Lioplacodes* (Fig. 4D), forms found in the upper Paleocene–lower Eocene Flagstaff Limestone of central Utah (La Rocque, 1960).

The upper member of the Skunk Ranch Formation, present only in section A (Fig. 1), where it is 136 m (446 ft) thick, consists of limestone- and chert-pebble conglomerate interbedded with medium- to coarse-grained litharenite. It was deposited by braided rivers (Wilson, 1991). The upper member is gradational on the middle member. It is truncated beneath a flat-lying succession of andesitic breccias and volcaniclastics that are probably broadly equivalent to the Rubio Peak Formation of middle Eocene age (Hodgson, 1991).

Sandstone beds of the Skunk Ranch Formation are sedimentary litharenites. Grain types include chert and carbonate lithic fragments derived from a sedimentary source terrane (Wilson, 1991).

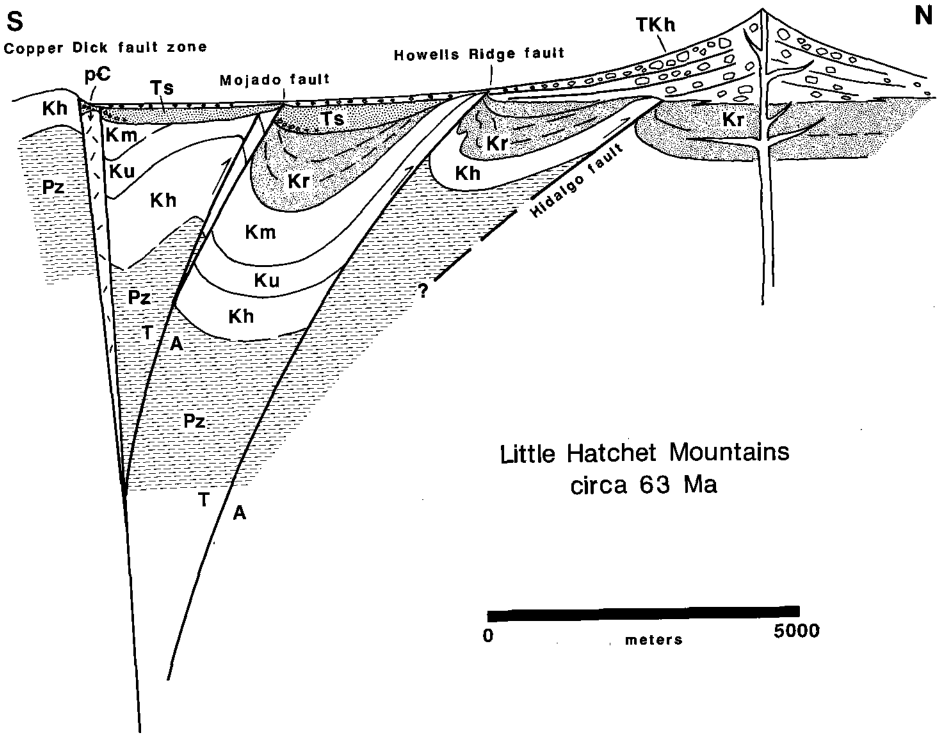

FIGURE 5—Schematic north-south cross section through area of Fig. 1 during deposition of middle member of Skunk Ranch Formation, showing partitioning of both Ringbone and Skunk Ranch depocenters during late Laramide deformation. Prior to this time, the Howells Ridge fault had served as an effective barrier to the transport of volcanic material south into the Skunk Ranch Formation. **p-C**, Precambrian rocks; **Pz**, Paleozoic strata, undifferentiated; **Kh**, Hell-to-Finish Formation; **Ku**, U-Bar Formation; **Km**, Mojado Formation; **Kr**, Ringbone Formation; **TKh**, Hidalgo Formation; **Ts**, Skunk Ranch Formation. No vertical exaggeration.

Discussion

Laramide sedimentary and volcanic strata described above record crustal deformation in southwestern New Mexico during a period extending from the late Campanian through the late Paleocene–early Eocene. Overlap of folded strata by a flat-lying volcanic succession that may be equivalent to the Rubio Peak Formation indicates that deformation at least predated the middle to late Eocene, but may have ceased earlier in the Eocene. The history of deformation recorded by sedimentary basin development accords well with observed crosscutting relationships and constrains more precisely the time during which Laramide events occurred than do structural relationships alone. The revised stratigraphy presented here indicates that basin evolution was complex and followed a two-stage history. The first stage is marked by the northward-thinning clastic wedge of the Ringbone, the second stage by the development of separate, roughly contemporaneous, epiclastic and volcanic depocenters recorded by the Skunk Ranch and Hidalgo Formations, respectively.

The Ringbone is interpreted to have accumulated during shortening accompanied by basement-block uplift, perhaps of transpressional origin (Seager, 1983; Seager and Mack, 1986). A basement-cored uplift, the Hidalgo uplift, lay southwest of the Ringbone depocenter (Seager and Mack, 1986). The sedimentary-clast conglomerate of the lower and upper members was shed northeastward from the uplift as erosion began to strip its Phanerozoic cover. It is also possible that some conglomerate of the lower member was shed from the north and northwest (Basabilvazo, 1991). Sandstone in the lower and middle members was deposited by axial-fluvial systems transporting volcanic detritus from the west and northwest. The ultimate source of the volcanic-lithic grains was probably the Jurassic and Cretaceous arc assemblage of south-central Arizona (e.g., Lipman and Sawyer, 1985; Lipman and Hagstrum, 1992).

The southern edge of Ringbone exposure coincides with the Mojado fault system (Hodgson, 1991), but the basin probably extended farther south in the Campanian. This is inferred from the presence of deformed, fine-grained lacustrine strata of the middle member adjacent to the fault (Fig. 1), indicating that it did not always form the basin margin. We tentatively regard the Ringbone Basin as an intermontane basin yoked to the Hidalgo uplift, with a thick proximal section that thinned toward the northeast.

The Ringbone Basin itself was deformed in the Maastrichtian. Uplift that accompanied the deformation partitioned the once-broad basin into two depocenters, one in which the Skunk Ranch was deposited and another, lying north of the Howells Ridge fault, in which the Hidalgo accumulated (Fig. 5). That deformation had begun to affect the Ringbone is suggested by eastward stepping of the Hidalgo onto pre-Ringbone rocks in the northern part of the study area (Fig. 1). Ringbone strata in that transition appear to thin beneath the sharp contact with the Hidalgo, indicative of at least local angular discordance.

Although the lateral relationships of the Skunk Ranch and Hidalgo Formations are imperfectly understood, structural and topographic separation of the two units must have existed to preserve the striking compositional contrast of those units. North of the Mojado fault, the Skunk Ranch section is largely concordant above the Ringbone, indicating that the absence of Hidalgo there is not due to uplift after Ringbone deposition. Moreover, the thin andesite flows and andesite clasts in the upper member of the Ringbone indicate probable geographic continuity with the Hidalgo depocenter. We suggest that basin partitioning subsequently separated the Hidalgo and Skunk Ranch depocenters, preventing influx of volcaniclastics into the southern depocenter prior to deposition of the middle member of the Skunk Ranch. Skunk Ranch deposition stepped southward onto the hanging wall of the Mojado fault, which had been previously marked by major uplift as all members of the Ringbone were deformed. Some movement on the fault nevertheless controlled thickness variation in the Skunk Ranch, resulting in a thick lower member on the footwall and a thin lower member on the hanging wall. We believe that the southward shift in the locus of Skunk Ranch deposition resulted from activation of a north-trending normal fault system that forms the eastern boundary of most Ringbone exposures and all Skunk Ranch exposures (Fig. 1). It thus appears that normal and reverse faulting were coeval on different structural trends.

Detritus in the Skunk Ranch was shed northward from a source terrane more proximal or more elevated than the terrane that served as the source of the Ringbone conglomerate beds. This is indicated by the large size of the boulders, their exclusive Lower Cretaceous derivation, and imbrication in the conglomerate (Wilson, 1991). Lower Cretaceous strata, including Hell-to-Finish, U-Bar, and Mojado

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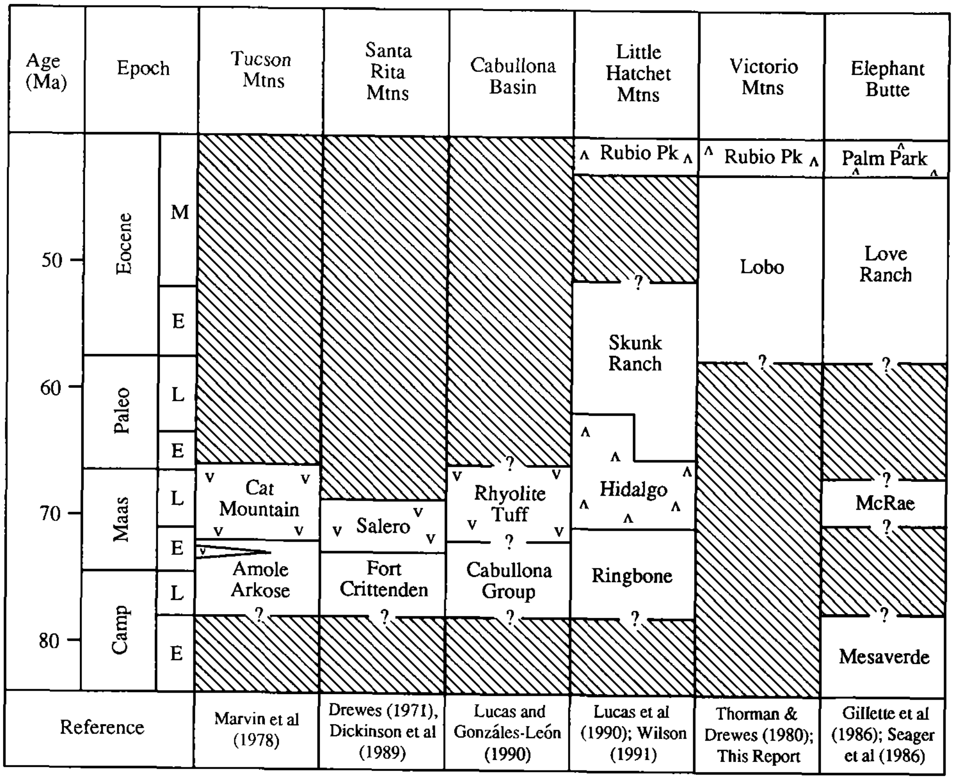

FIGURE 6—Correlation of Upper Cretaceous–Paleogene sedimentary and volcanic units in the Little Hatchet Mountains with units of southeastern Arizona, northern Sonora, and south-central New Mexico. Late Cretaceous age of Amole Arkose based on interfingering relationships with Confidence Peak Tuff (P. W. Lipman, pers. comm. 1990). Age of Hidalgo Formation depicted taken from range of published ages in Little Hatchet Mountains discussed in text. Modified from Lawton and Clemons (1992). Time scale from Harland et al. (1990). Volcanic symbols: v, silicic volcanic unit; inverted v, intermediate volcanic unit.

beds, are presently exposed south of the Skunk Ranch Formation, across the Copper Dick fault (Fig. 1). This area, which lies well to the north of the postulated extent of the Hidalgo uplift of Seager and Mack (1986), probably served as the source for Skunk Ranch conglomerate and sandstone.

The Skunk Ranch depocenter was shielded from volcanic influence prior to the appearance of flow breccias in the basin (Fig. 5). The Paleocene ages reported from the Hidalgo in the Little Hatchets (Loring and Loring, 1980) are compatible with the biostratigraphic Paleocene–Eocene age of the middle member of the Skunk Ranch. Therefore, we provisionally regard the andesite as a southern extension of the Hidalgo volcanic pile and infer at least partial contemporaneity of the Skunk Ranch and Hidalgo Formations (Fig. 6).

The basins that developed in the Little Hatchet Mountains provide support for recent interpretations of two episodes of Laramide deformation in southwestern New Mexico. Rosaz (1989) postulated a two-phase Laramide event consisting of a Maastrichtian–Paleocene episode of basement-block uplift and northeast-vergent thrusting followed by a Paleocene–Eocene episode of strike-slip faulting on faults oriented N60W. Hodgson (1991) proposed a similar scenario involving a latest Cretaceous early Laramide stage of basement-cored uplift along northwest-trending reverse faults and a Paleocene–Eocene late Laramide stage of convergent wrenching, resulting in strike-slip movement along the same fault systems. Our present understanding of the ages of Laramide units in the Little Hatchet Mountains better supports the Laramide timing suggested by Hodgson. Moreover, the temporal and geographic shift in loci of deposition between the Ringbone and Skunk Ranch Formations, the latter to a fault block that had previously been marked by uplift, supports the interpretation that subsidence mechanism, and thus style of deformation, evolved in the course of the Laramide. This shift in uplift pattern probably resulted from the formation of a north-trending system of normal faults (Fig. 1) that appear to have overlapped in time with the widespread reverse faulting in the range. Concurrence of contractional and extensional structures lends strong support to wrench-fault models (e.g., Wilcox et al., 1973) of Laramide tectonism (Seager, 1983; Rosaz, 1989; Hodgson, 1991). The depositional record alone may not resolve the issue of two separate deformational stages, as opposed to an evolutionary change in style, but the evidence for continuing deformation during onset of Hidalgo volcanism suggests that the change was gradual.

The Laramide stratigraphy of the Little Hatchet Mountains, if correlated with units in southeastern Arizona and south-central New Mexico, provides a unique link between sedimentary basins formed to the southwest in Arizona and northern Sonora and basins formed on the craton (Fig. 6). The basins of southeastern Arizona and northern Sonora contain Upper Cretaceous rocks correlative with the Ringbone Formation. The correlative strata are similar in appearance and depositional environment to the Ringbone and overlie Lower Cretaceous rocks of the Bisbee Basin. In contrast, with the exception of the depocenter occupied by the McRae Formation (Fig. 6), Laramide basins to the northeast of the Little Hatchet Mountains contain strata equivalent to the upper part of the Skunk Ranch Formation. These units typically overlie Paleozoic strata or basement and are overlain by andesitic units correlative with the Rubio Peak. They accumulated in sedimentary basins formed adjacent to basement-cored uplifts in the craton (e.g., Seager et al., 1986). Thus, Laramide basins in the geographic area encompassed by the Early Cretaceous Bisbee Basin formed during a brief period in the late Campanian and early Maastrichtian. These basins appear to be older than cratonic Laramide basins immediately to the north, which formed in the Paleocene and early Eocene.

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